Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

In the Matter of	)	
	)	
Further Streamlining Part 25 Rules Governing Satellite Services	)	IB Docket No. 18-314
	)	
	)	

**COMMENTS OF THE
NATIONAL ACADEMY OF SCIENCES'
COMMITTEE ON RADIO FREQUENCIES**

The National Academy of Sciences, through its Committee on Radio Frequencies (hereinafter, CORF[1]), hereby submits its comments in response to the Commission's November 15, 2018, *Notice of Proposed Rulemaking* (NPRM) in the above-captioned dockets. In these comments, CORF addresses concerns regarding potential interference to protected passive scientific observations from out-of-band and spurious emissions from satellite transmissions, and the proposal to revise Section 25.202(f) of the Commission's rules.

I. The Role of Radio Astronomy and Earth Remote Sensing, and the Unique Vulnerability of Scientific Services to Interference.

CORF has a substantial interest in this proceeding, as it represents the interests of scientific users of the radio spectrum, including users of the Radio Astronomy Service (RAS) and Earth Exploration-Satellite Service (EESS) bands. These users perform extremely important, yet vulnerable, research.

1 See the Appendix for the membership of the Committee on Radio Frequencies.

A. Radio Astronomy

As the Commission has also long recognized, radio astronomy is a vitally important tool used by scientists to study our universe. It was through the use of radio astronomy that scientists discovered the first planets outside the solar system, circling a distant pulsar. The Nobel Prize winning discovery of pulsars by radio astronomers has led to the recognition of a widespread population of rapidly spinning neutron stars with gravitational fields at their surface up to 100 billion times stronger than on Earth's surface. Subsequent radio observations of pulsars have revolutionized understanding of the physics of neutron stars and have resulted in the first experimental evidence for gravitational radiation, which was recognized with the awarding of another Nobel Prize. Radio astronomy has also enabled the discovery of organic matter and prebiotic molecules outside our solar system, leading to new insights into the potential existence of life elsewhere in the Milky Way galaxy. Radio spectroscopy and broadband continuum observations have identified and characterized the birth sites of stars in the Milky Way, the processes by which stars slowly die, and the complex distribution and evolution of galaxies in the universe. The enormous energies contained in the enigmatic quasars and radio galaxies discovered by radio astronomers have led to the recognition that most galaxies, including our own Milky Way, contain supermassive black holes at their centers, a phenomenon that appears to be crucial to the creation and evolution of galaxies. Synchronized observations using widely spaced radio telescopes around the world give extraordinarily high angular resolution, far superior to that which can be obtained using the largest optical telescopes on the ground or in space.

The critical scientific research undertaken by RAS observers, however, cannot be performed without access to interference-free bands. Notably, the emissions that radio astronomers receive are extremely weak—a radio telescope receives less than 1 percent of one-billionth of one-billionth of a watt (10^{-20} W) from a typical cosmic object. Because radio astronomy receivers are designed to pick up such remarkably weak signals, radio observatories are particularly vulnerable to interference from in-band emissions, spurious and out-of-band emissions from licensed and unlicensed users of neighboring bands, and emissions that produce harmonic signals in the RAS bands, even if those human-made emissions are weak and distant.

B. Earth Remote Sensing—EESS

The Commission has also long recognized that satellite-based Earth remote sensing, particularly sensing by users of the microwave EESS bands, is a critical and uniquely valuable resource for monitoring the Earth and its environment. Satellite-based microwave remote sensing presents a global perspective and, in many cases, is the only practical method of obtaining atmospheric and surface data for the entire planet, particularly when optical remote sensing is blocked by clouds or attenuated by water vapor. Instruments operating in the EESS bands provide data that are important to human welfare and security and provide critical information for scientific research, commercial endeavors, and government operations in areas such as defense, security, meteorology, atmospheric chemistry, climatology, and oceanography. Examples are measurement of parameters—such as ocean surface temperature, wind velocity, salinity, sea surface elevation, significant wave height, snowfall, and precipitation rate over the ocean—needed to understand ocean circulation and the associated global redistribution of heat and its interaction with the atmosphere. They also include monitoring soil moisture, a parameter needed for agriculture, flood, and drought assessment; for weather prediction; and for defense in connection with planning military deployment, assessing trafficability, and surveillance, among many other applications. Passive microwave sensors are also used to provide temperature and humidity profiles of the atmosphere critical for weather forecasting, information to monitor changes in polar sea and land ice cover in the persistently cloudy polar regions, and direct measurements useful in assessing hazards such as hurricanes, wildfires, and drought. Indeed, our ability to produce improved weather forecasts is due in part to the high-quality data that comes from satellite-borne passive sensors that observe the entire world in a consistent and timely manner. Users of these data include the National Oceanic and Atmospheric Administration (NOAA), the National Science Foundation (NSF), the National Aeronautics and Space Administration (NASA), the U.S. Department of Defense (DOD), the U.S. Department of Agriculture (USDA), the U.S. Geological Survey (USGS), the U.S. Agency for International Development (USAID), the Federal Emergency Management Agency (FEMA), the U.S. Forest Service (USFS), and the U.S. intelligence community. Most of these data sets are also available free to anyone anywhere in the world.

Passive instruments in space are particularly vulnerable to human-made emissions because they rely on very weak signals emitted naturally from the Earth's surface and atmosphere. . These weak signals require the sensors to integrate over space and time, which makes the measurements even more sensitive to competing human-made signals present in these averages. This is especially a concern for EESS because sensors in space monitor globally and view large swaths of the surface at one time and are thus subject to aggregate interference from all emitters in the area scanned. In this sense, the issue for EESS differs from that of RAS, which generally involves receivers at fixed locations that often can be protected with regionally specific restrictions.

In sum, the important science performed by radio astronomers and Earth remote sensing scientists cannot be performed without access to interference-free bands. Loss of such access constitutes a loss for the scientific and cultural heritage of all people, as well as a loss of the practical applications enabled by this access, which can include financial loss arising from impaired weather forecasting and climate monitoring. CORF generally supports the sharing and flexible use of frequency allocations where practical, but protection of passive scientific observations, as discussed herein, must be addressed.

II. The Impact of Satellite Out-of-Band and Spurious Emission Interference on Passive Services.

As the Commission has long recognized, passive services such as radio astronomy are particularly vulnerable to the damaging effects of interference from spurious and out-of-band emissions (OOBE).[2] For radio astronomy, these interfering signals are routinely detected and can appear somewhat like spectral lines. In some

[2] For example, in 1998, the Commission noted that "radio astronomy operations utilize some of the most sensitive instruments made and even unwanted emissions through zero dB sidelobes may completely destroy observations." *See* Amendment of Parts 2 and 25 of the Commission's Rules to Permit Operation of NGSO FSS Systems, *Notice of Proposed Rulemaking,* 14 FCC Rcd. 1131, 1173 (1998).

cases, they can be recognized and potentially corrected for, but their removal is time-consuming and often frustrating, resulting in a reduction in efficiency. However, many unwanted signals are not easily recognizable, and can masquerade as valid scientific data.

As discussed in *The Handbook of Frequency Allocations and Spectrum Protection for Scientific Uses, Second Edition*, the most serious cases of interference to radio astronomy during recent years have resulted from transmitters on satellites producing unwanted emissions that fall within radio astronomy bands. An example of interference from a geostationary orbit (GSO) satellite in a band adjacent to a radio astronomy band is provided by a European television broadcast satellite transmitting in the Fixed Satellite Service band 10.7-10.95 GHz. A measured spectrum showed that at 10.7 GHz, the upper edge of a primary radio astronomy band, the spectral power flux density from the satellite was approximately 39 dB greater than the corresponding threshold value for continuum observations in Table 1 of Recommendation ITU-R RA.769. The resulting radiation into the 10.6-10.7 GHz radio band made that band completely unusable for observations by the 100 m radio telescope at Effelsberg, Germany.[3]

Interference from GSO satellites presents a special problem, because a constellation of interfering satellites distributed along the orbit could preclude science observation within a band of sky centered on the orbit. The apparent declination of the orbit varies by approximately 10 degrees as seen from observatories at intermediate

[3] For further discussion, see Chapter 6 in the *ITU Handbook on Radio Astronomy* (2013 edition).

latitudes in the Northern and Southern Hemispheres of Earth (see Figure 1 in Annex 1 of Recommendation ITU-R RA.517, or see ITU-R RA.611). Thus, the whole sky can be observed if observations can be made to within 5 degrees of the orbit from observatories in both hemispheres. In the sidelobe model in Recommendation ITU-R SA.509, the sidelobe gain at 5 degrees from the main-beam axis is 15 dBi, so values of the detrimental thresholds for such observations are 15 dB lower than those based on a sidelobe gain of 0 dBi, as in the tables in Recommendation ITU-R RA.769. It is desirable that these lower detrimental thresholds be applicable to unwanted emissions from GSO satellites.[4]

Examples of interference from non-geostationary orbit (NGSO) satellites can be found with the Russian Global Navigation Satellite System (GLONASS; 1602.5625-1615.5 MHz) and the Iridium constellation (1618.25-1626.5 MHz), which interfere with RAS operations in the 1610.6-1613.8 MHz and 1660-1670 MHz bands. Interferences of this type have been due to out-of-band emissions from lack of pulse shaping, poor control of modulation sidelobes in the frequency domain, and intermodulation products generated on the satellite caused by driving the transmitter amplifiers into compression in order to improve on efficiency. Because of their constant motion, constellations of NGSO satellites such as these have the potential for being particularly disruptive to the passive services because of their constantly changing configuration and their near-constant coverage of Earth's surface.

[4] For further discussion, see Chapter 4 of the *ITU Handbook on Radio Astronomy* (2013 edition).

In the case of GLONASS, improvements have been made by no longer launching spacecraft with frequency capacity higher than 1610 MHz, and of those that do launch, all are equipped with out-of-band filters. It remains to be seen if Iridium's NEXT generation satellite constellation will reduce its current harmful level of OOBE.

In contrast to radio telescopes that point from Earth to space, EESS sensors point in the opposite direction, from space to Earth. The rapid motion of NGSO satellite-based sensors through space for EESS remote sensing limits the integration time available for sensor measurements to seconds, compared with the longer integration times used by stationary radio telescopes. Hence, when interference does occur to the sensor, it is more difficult to correct or compensate and so the data is often flagged simply as being lost. Further, there is no established way to detect and reject EESS data that are contaminated with low-level interference—that is, interference that cannot be differentiated from signals originating from background thermal emission. The propagation of such undetected contaminated data into numerical weather- and climate-prediction models may have a significant destructive impact on the reliability or quality of weather forecasting. In other cases, observations may be partially obscured or denied completely owing to strong out-of-band, spurious, or weak in-band emissions affecting regional or broad-area measurements.

III. Addressing Satellite OOBE into Passive Service Bands.

At paragraphs 18-19 of the NPRM, the Commission proposes to replace the current limits on satellite OOBE as set forth in Section 25. 202(f) of the rules with the provisions in Recommendation ITU-R SM.1541-6. CORF takes no position on the adoption of ITU-R SM.1541-6 as applied generally to satellite bands where the adjacent bands are active services. However, where satellite transmissions are adjacent to a passive service band, the provisions of ITU-R SM.1541-6 are unlikely to provide a mask sufficient to provide the protection that passive services need or are entitled to. CORF notes that a requirement for more stringent OOBE masks in these adjacent frequency bands is consistent with the language in Section 4 of ITU-R SM.1541-6, where it is acknowledged that "the spectrum limits specified in this Recommendation should be regarded as generic limits, which generally constitute the least restrictive OoB emission limits successfully used as national or regional regulations. These are sometimes called safety net limits. They are intended for use in bands where tighter limits are not otherwise required to protect specific applications." It is also noted in Section 4 that "[t]he development of more specific OoB domain emission limits for each system and in each frequency band should be encouraged by administrations. These limits ... would take care about co-frequency or adjacent bands operating systems, with a view to enhancing compatibility with other radio services." Accordingly, regardless of whether the Commission keeps Section 25.202(f) or replaces it with reference to Recommendation ITU-R SM.1541-6, it should add provisions specifically providing adjacent passive bands the necessary higher level of protection.

Because of the vulnerability of passive observations to OOBE, certain international and domestic footnotes already specifically <u>prohibit</u> the transmission of OOBE into passive bands. For example, International Footnote 5.340 provides that "[a]ll emissions are prohibited" in numerous RAS/EESS bands, including some that have satellite services in adjacent or nearly adjacent bands: 10.68-10.7 GHz, 15.35-15.4 GHz, 31.3-31.5 GHz, 31.5-31.8 GHz, 48.94-49.04 GHz, 52.6-54.25 GHz, and 86-92 GHz. Similarly, US Footnote 246 provides that "[n]o station shall be authorized to transmit" in certain passive bands adjacent to bands allocated to satellite services: 1660.5-1668.4 MHz, 4990-5000 MHz, 10.68-10.7 GHz, 15.35-15.4 GHz, 31.3-31.8 GHz, 50.2-50.4 GHz, 52.6-54.25 GHz, and 86-92 GHz.[5]

Other footnotes specifically require enhanced protection of radio astronomy facilities from OOBE. For example,

- International Footnote 5.443.B provides a specific level of OOBE protection for RAS observations at 4990-5000 MHz from Radionavigation Satellite Services at 5010-5030 MHz;

- International Footnote 5.551.H provides a specific level of OOBE protection for RAS observations at 42.5-43.5 GHz from NGSO Fixed Satellite and Broadcasting Satellite Services operating at 42-42.5 GHz;

- International Footnote 5.551.I provides a specific level of OOBE protection for RAS observations at 42.5-43.5 GHz from GSO Fixed Satellite Service and Broadcasting Satellite Service operating at 42-42.5 GHz; and

- International Footnote 5.208B provides a specific level of OOBE protection (as set forth in ITU Resolution 739, Tables 1-1 and 1-2) for RAS observations in certain bands, including 137-138 MHz, 387-390 MHz, 400.15-401 MHz, 1452-1492 MHz, 1525-1610 MHz, and 1613.8-1626.5 MHz.[6]

International Footnote 5.388A provides a specific level of OOBE protection (as set forth in ITU Resolution 750, Table 1-1) to EESS observations at 1350-1400 MHz, 1427-1452

5 Additional passive bands above 92 GHz are also protected in Footnotes 5.340/US 246.

6 Similarly, International Footnote 5.208A states that "[i]n making assignments to space stations in the mobile-satellite service in the bands 137-138 MHz, 387-390 MHz and 400.15-401 MHz, administrations shall take all practicable steps to protect the radio astronomy service in the bands 150.05-153 MHz, 322-328.6 MHz, 406.1-410 MHz and 608-614 MHz from harmful interference from unwanted emissions. The threshold levels of interference detrimental to the radio astronomy service are shown in the relevant ITU-R Recommendation." In this case, the "relevant ITU-R Recommendation" would be Recommendation ITU-R RA.769.

MHz, 22.55-23.55 GHz, 30-31.3 GHz, 49.7-50.2 GHz, 50.4-50.9 GHz, 51.4-52.6 GHz, 81-86 GHz, and 92-94 GHz.

In passive bands not specifically protected from OOBE by international or domestic footnotes, then by default, the provisions of Recommendation ITU-R RA.769 apply to protection of RAS bands from OOBE,[7] and the provisions of ITU-R RS.2017 apply to the protection of EESS bands from OOBE. Where RAS and EESS share an allocation, then the satellite operator must limit OOBE to whichever level is more stringent.

Thus, passive bands are either protected at a specific level from OOBE by a specific international or domestic footnote, or are protected at specific levels set forth in Recommendations ITU-R RA.769 or ITU-R RS.2017. In either case, those specific levels of protections should be implemented in any new satellite OOBE rule.[8]

IV. The Commission Should Retain Provisions Addressing Spurious Emissions and Giving the Commission Additional Flexibility to Address Harmful Interference.

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[7] The Commission has previously ordered use of ITU-R RA.769-1 as the standard for limits on satellite OOBE. For example, in 2000 the Commission did so for NGSO satellites, noting that "[t]he interference limits set forth in ITU-R RA.769-1 provide reasonable protection against interference to RAS operations from various [NGSO] operations." *See* Amendment of Parts 2 and 25 of the Commission's Rules to Permit Operation of NGSO FSS Systems, *First Report and Order,* 16 FCC Rcd. 4096, 4191 (2000). *See also* In the Matter of Flexibility for Delivery of Communications by Mobile Satellite Service Providers, *Report and Order*, 18 FCC Rcd. 1962, 2049, Para. 175 (2003), wherein the Commission required operators of satellite ancillary terrestrial components to "take all practicable steps to avoid causing interference to U.S. RAS observations in the 1660-1660.5 MHz band, consistent with Recommendation ITU-R RA.769-1 of the International Radio Regulations."

[8] While OOBE limits are critical to the protection of passive bands, coordination between satellite operators and radio astronomy facilities provides critical protection as well. Compliance with rules providing OOBE limits does not exempt a satellite operator from any additional coordination requirements specified in the Commission's rules. *Cf.* ITU-R SM.1541-6 at page 8, Section 4 ("Compliance with emission limits contained in this Recommendation may not preclude the occurrence of interference. Therefore, compliance with the standard does not obviate the need for cooperation in resolving and implementing engineering solutions to harmful interference problem.").

Section III.D of the NPRM is titled “Out-of-Band Emissions” and addresses proposed changes to Section 25.202(f) of the Commission’s rules. That rule section is currently titled “Emission Limits” and is not limited solely to OOBE, but rather also addresses spurious emissions in Section 25.202(f)(3).[9] However, the revision to 25.202(f) proposed in the NPRM appears to refer only to OOBE and to remove reference to unwanted spurious emissions (current Section 25.202(f)(3)). The proposed language also appears to remove the ability of the Commission, at its discretion, to require greater attenuation in order to prevent harmful interference (current Section 25.202(f)(4)).

CORF understands that the Commission is attempting to clarify the understanding of its OOBE standards by adopting ITU-R SM.1541-6, but that document explicitly applies only to unwanted emissions in the “out-of-band domain,” and not to unwanted emissions in the “spurious domain,” which, as the document acknowledges, is “the frequency range beyond the OoB domain in which spurious emissions generally predominate.”[10] Clear rules regarding unwanted spurious emissions—including harmonic emissions, parasitic emissions, intermodulation products, and frequency conversion products—are necessary to enable effective use and sharing of radio frequencies, regardless of the source and service designation of the transmitter. Elimination of limits on satellite spurious emissions would be devastating to users in

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[9] Typically, “out-of-band emissions” refers to emissions on a frequency or frequencies *immediately* outside the necessary bandwidth that results from the modulation process, but excluding spurious emissions. “Spurious emissions,” on the other hand, are typically defined as emissions on a frequency or frequencies that are outside the necessary bandwidth and the level of which may be reduced without affecting the corresponding transmission of information. Spurious emissions include harmonic emissions, parasitic emissions, intermodulation products, and frequency conversion products, but exclude out-of-band emissions.

[10] ITU-R SM.1541-6 at page 3, Section 1.1.

numerous services, including the satellite services, terrestrial services, and users of the passive bands. CORF does not believe that the Commission intended this effect with its proposed revisions to the text of Section 25.202(f). Nevertheless, it must now address this issue.

The Commission could address the issue by revising its proposed language so that reference is made to ITU-R SM.1541-6 for OOBE, while retaining the existing language of Section 25.202(f)(3) for spurious emissions. Alternatively, Section 25.202(f)(3) could be revised to reference ITU-R SM.329-12 ("Unwanted Emissions in the Spurious Domain"). If the Commission plans to adopt the regulations in ITU-R SM.329 for unwanted spurious emissions, it should seek additional comments on whether ITU-R SM.329-12 is an appropriate standard.

Furthermore, as noted above, the proposed language in the NPRM appears to remove the ability of the Commission, at its discretion, to require greater attenuation in order to prevent harmful interference (current Section 25.202(f)(4)). To protect both the passive services and other services that could be harmed by the implementation of the general OOBE limits described in ITU-R SM.1541-6, the revised 25.202(f) must continue to include an explicit statement that the Commission reserves the right to require greater attenuation when emission outside the authorized bandwidth causes harmful interference. There is no rational reason why the Commission should not retain language <u>explicitly</u> authorizing itself, at its own discretion, to do so.

V. Conclusion

The important science performed by radio astronomers and Earth remote sensing scientists cannot be performed without access to interference-free bands. Loss of such access constitutes a loss for the scientific and cultural heritage of all people, as well as a loss of the practical applications enabled by this access, which can include death, injury, and financial loss arising from impaired weather forecasting and climate monitoring. Accordingly, regardless of whether the Commission keeps Section 25.202(f) or replaces it with reference to Recommendation ITU-R SM.1541-6, it should add provisions as discussed above, specifically providing passive bands the necessary higher level of protection from spurious and out-of-band emissions, and language explicitly authorizing the Commission to require greater attention when emission outside the authorized bandwidth causes harmful interference.

Respectfully submitted,

NATIONAL ACADEMY OF SCIENCES'
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